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RESEARCH MEMORANDUM

for the

Bureau of Aeronautics, Department of the Navy

LONGITUDINAL TRIM AND TUMBLE CHARACTERISTICS OF A 0.057-SCALE MODEL OF THE CHANCE VOUGHT XF7U-1 AIRPLANE - TED NO. NACA DE311

By

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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

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SUMMARY

The longitudinal trim and tumble characteristics over a large angle-of-attack range have been investigated in the Langley 20-foot free-spinning tunnel for a 0.057-scale model of the Chance Vought XF7U-1 airplane for various center-of-gravity locations. The effects of opening the speed brakes and of extending the slats were also determined. The investigation included tests to determine the parachute requirements for recovery from a tumble, and brief tests were also performed to determine if the pilot could escape from the airplane during a tumble. The acceleration at the pilot's head during a tumble was computed.

The results indicated that the model would not trim at any angle of attack at which it could not be controlled. The model would not tumble unless the center of gravity was located rearward as far as 24 percent of the mean aerodynamic chord and then only if slats were extended, elevators were full up, and the model given an initial positive pitching motion. The tumbling motion obtained could be readily terminated by deflecting the elevators full down so as to oppose the rotation, or by the simultaneous opening of two wing-tip parachutes whose diameters were 4 feet or larger and whose drag coefficients were approximately 0.7. Model results indicate that the pilot will not be struck by the airplane if it becomes necessary to leave the airplane during a tumble. It was indicated that the acceleration encountered during a tumble may be dangerous to the pilot unless the tumble is terminated immediately upon its inception.

INTRODUCTION

At the request of the Bureau of Aeronautics, Department of the Navy, tests have been performed in the Langley 20-foot free-spinning tunnel to determine the spin and recovery characteristics and the tumbling tendencies of a 0.057-scale model of the Chance Vought XF7U-1 airplane. The results of the spin-recovery tests have been presented in reference 1, and the results of the tumble tests are presented herein. Tumbling is described as a continual rotation of an object about its lateral axis in a free fall while the lateral axis maintains a direction normal to the relative wind. Additional tests were made to determine the longitudinal trim characteristics over a large angle-of-attack range inasmuch as some airplanes of unconventional design have been known to trim above the stall, at an attitude where the pilot had no control.

The airplane represented by the model is a single-place fighter, powered by twin jets which are housed in the fuselage. The airplane has no horizontal tail, but does have twin vertical tails with rudders for directional control. The longitudinal and lateral controls are combined into one pair of surfaces known as "ailavators." The airplane is equipped with leading-edge slats and speed brakes.

The longitudinal trim characteristics of the model were determined with the model mounted with freedom in pitch only. In these tests the effects of longitudinal shifts of the center-of-gravity location, extension of the slats, and opening of the speed brakes were determined. The tumble tests, made with the model completely free, were conducted for the normal combat-fighter weight. The effects on tumbling of center-of-gravity movements, of opening speed brakes, and of extending slats were ascertained. The tests with freedom in pitch and the tumble tests were supplemented by six-component-force tests over an angle-of-attack range from 0° to 90°. Tests were also performed to determine the parachute requirements for recovery from a tumble and to determine if the pilot could escape from the tumbling airplane. From an analysis of the motion of the tumbling model, approximate calculations were made of the accelerations that would be experienced at the pilot's head during a tumble.

SYMBOLS

b	wing span, feet
S	wing area, square feet
c	wing chord at any station y along the span

$\bar{c}$ mean aerodynamic chord, feet

$x/\bar{c}$ ratio of distance of center of gravity rearward of leading edge of mean aerodynamic chord to mean aerodynamic chord

$z/\bar{c}$ ratio of distance between center of gravity and root chord line to mean aerodynamic chord (positive when center of gravity is below root chord line)

m mass of airplane, slugs

I_X, I_Y, I_Z moments of inertia about X-, Y-, and Z-body axes, respectively, slug-feet^2

$\frac{I_X - I_Y}{mb^2}$ inertia yawing-moment parameter

$\frac{I_Y - I_Z}{mb^2}$ inertia rolling-moment parameter

$\frac{I_Z - I_X}{mb^2}$ inertia pitching-moment parameter

ρ air density, slug per cubic foot

μ relative density parameter $\left(\frac{m}{\rho Sb}\right)$

V full-scale value of tunnel airspeed, feet per second

V_t full-scale velocity of center of gravity along its trajectory, feet per second

q dynamic pressure, pounds per square foot $\left(\frac{1}{2}\rho V^2\right)$

α angle of attack, degrees

ψ angle of yaw, degrees (positive when nose of airplane is to right of flight path)

ϵ angle between root chord line and a line through center of gravity and pilot's head (11° for this design)

δ_e elevator deflection, degrees (positive when trailing edge is deflected down)

C_m pitching-moment coefficient $\left(\frac{\text{Pitching moment}}{qS\bar{c}}\right)$

C_L lift coefficient $\left(\frac{\text{Lift}}{qS}\right)$

C_D drag coefficient $\left(\frac{\text{Drag}}{qS}\right)$

r distance from center of gravity to pilot's head, feet

t time, seconds (taken to be zero the instant the record of motion began)

θ angular displacement of airplane about its Y-axis, radians ($\theta = 0$ when $t = 0$)

Ω angular velocity of pilot's head about Y-axis, radians per second $\left(\Omega = \frac{d\theta}{dt}\right)$

g acceleration due to gravity, 32.2 feet per second per second

a_c centripetal acceleration at pilot's head due to angular velocity of airplane about its Y-axis, g units

a_o angular acceleration of airplane about Y-axis, radians per second per second

a_A tangential acceleration at pilot's head due to the angular acceleration of the airplane about its Y-axis, g units

a resultant acceleration at pilot's head, g units

a' component of acceleration directed through long axis (assumed perpendicular to root chord line) of the pilot (positive when pilot is pushed down into seat), g units

a'' component of acceleration directed normal to long axis (parallel to root chord line) of the pilot (positive when pilot is pushed against back of seat, g units

APPARATUS AND METHODS

Model

The 0.057-scale model of the Chance Vought XF7U-1 airplane used for the spin investigation (reference 1) was also used for the trim and tumble investigation. The model was furnished by the Bureau of Aeronautics,

Department of the Navy, and was checked for dimensional accuracy and prepared for investigation by the Langley Laboratory. Dimensional characteristics of the airplane represented by the model are given in table I and a three-view drawing of the model as tested in the clean condition (landing gear, slats, and speed brakes retracted) is presented in figure 1. Figures 2, 3, and 4 are photographs of the model in the clean condition, with slats extended and with the speed brakes open, respectively. The model as received and tested had partial-span slats although subsequent redesign incorporates approximately full-span slats on the airplane. For the tumble tests, the model was ballasted by means of lead weights to obtain dynamic similarity to the airplane at an altitude of 15,000 feet (ρ = 0.001496 slug per cu ft). A remote-control mechanism was installed in the model to release the tumble-recovery parachutes for the parachute tests and to release the pilot for the pilot-escape tests. The parachutes used were of the flat circular type, made of silk, and had a drag coefficient of approximately 0.7 based on the laid-out-flat-surface area. The pilot was ballasted to obtain dynamic similarity to a 6-foot pilot weighing 200 pounds at an altitude of 15,000 feet.

For the longitudinal trim tests, small chordwise extensions were attached to the wing tips to facilitate suspension of the model in the vertical air stream so that it would be free to pitch about the desired center-of-gravity position. (See fig. 5.)

Wind Tunnel and Testing Technique

The longitudinal trim and tumble tests were performed in the Langley 20-foot free-spinning tunnel which is similar to the 15-foot free-spinning tunnel described in reference 2. The data presented have been converted to corresponding full-scale values by methods also described in reference 2. The force tests were conducted on a six-component strain-gage balance mounted in the Langley 20-foot free-spinning tunnel as shown in figure 6.

Longitudinal trim tests.- For the investigation of the longitudinal trim characteristics, the model was mounted on a rig (fig. 5) at its center of gravity in such a manner that the stability Y-axis was the only axis of freedom (freedom in pitch). Provision was made for tests about two center-of-gravity locations. At the test airspeed the model was displaced from its normal trimmed position and moved through a range of $\pm 90^{\circ}$ angle of attack by means of strings attached to the nose and tail of the model. The strings were attached in such a manner that when they were released their influence on the trim angle of attack was negligible. When the strings were released, the model assumed its trim angle of attack which was photographed and also recorded by visual observation.

Tumble tests.– Several methods of launching the model were employed in the tumble tests. To determine if the model would start tumbling of its own accord, the model was dropped without rotation into the vertically rising air stream with the nose pointing vertically upward (180° angle of attack) which simulated the attitude immediately before a whip stall (a stall from which the nose whips violently and suddenly downward). The model was also similarly dropped with the nose pointing horizontally (90° angle of attack) which simulated partial recovery from a whip stall. To determine if the model would tumble as a result of an external pitching moment, the model was also launched into the tunnel with positive and negative initial pitching rotation. When the model tumbled, it usually made five or six complete rotations before striking the safety net on the opposite side of the tunnel from which it was launched. For the parachute-recovery and pilot-escape tests, the parachutes were opened or the dummy pilot was released, as the case may be, after two or three complete rotations of the tumble. The pilot-escape tests simulated conditions where the pilot had climbed to the top of the cockpit and was ready to jump free of the airplane. Each test was photographed with a motion-picture camera in order that the behavior of the model could be studied more closely.

Method of Computation of Accelerations

Inasmuch as the head is the most vulnerable part of the body with regard to accelerations, the accelerations at the pilot's head were computed. The resultant acceleration of the pilot's head with respect to the earth is the vectorial sum of the tangential and normal acceleration along and normal to the trajectory of the center of gravity, respectively, plus the centripetal acceleration a_c due to angular velocity of the airplane about its center of gravity and the tangential acceleration a_A due to angular acceleration a_o of the airplane about its center of gravity. The path of motion of the model during a tumble was obtained with a stationary motion-picture camera.

The model motion was transposed into corresponding full-scale motion and plotted in figure 7. This path of motion was used in calculating the centripetal acceleration a_c and tangential acceleration a_A by graphical differentiation of the displacement curves, by use of the formulas:

$$a_c = \frac{\Omega^2 r}{g} = \left(\frac{d\theta}{dt}\right)^2 \frac{r}{g}$$

$$a_A = a_o \frac{r}{g} = \frac{d^2\theta}{dt^2} \frac{r}{g}$$

The slopes $\frac{d\theta}{dt}$ and $\frac{d^2\theta}{dt^2}$ were obtained from figure 8 and were arbitrarily taken at instances half-way between the recorded intervals of time.

The normal acceleration of the center of gravity was neglected inasmuch as the curvature of the trajectory of the center of gravity was very small. The tangential acceleration of the center of gravity due to variation in velocity along its trajectory was determined by the method used to determine a_c and a_A. Because tangential acceleration was very small it was neglected. Further investigation to estimate the magnitude of the tangential acceleration of the center of gravity by analysis of the variation in drag along the trajectory further proved that the tangential acceleration was small (less than 1 g). The approximate resultant components of acceleration directed through and normal to the long axis of the pilot are then, respectively:

$$a' = a_c \sin \epsilon + a_A \cos \epsilon$$

$$a'' = a_c \cos \epsilon + a_A \sin \epsilon$$

and the resultant acceleration a is the vectorial sum of its components, a' and a''.

The same results could be obtained more directly by determining the tangential and normal acceleration from the trajectory of the pilot's head. This method does not lend itself so readily, however, to the solution of accelerations for other points in the airplane as does the method presented.

PRECISION

The trim and tumble results presented herein are believed to be the true values given by the model within the following limits:

α, degrees . . . . ± 1
V, percent . . . . ± 5

The values of acceleration given herein are believed to be the true values existing on the model within ± 20 percent.

Little can be stated about the precision of the pilot-escape tests, except that if the dummy pilot is observed to clear all parts of the model by a large margin after being released, it is believed that the pilot of the corresponding airplane, after he has jumped, will not be struck by any part of the airplane.

Because of the impracticability of ballasting the model exactly and because of inadvertent damage to the model during tests, the measured weight and mass distribution of the model varied from the true scaled-down values within the following limits:

Weight, percent	0 to 2 high
Center-of-gravity location, percent $\bar{c}$	0 to 1 rearward

Moments of inertia:

I_X, percent	0 to 4 high
I_Y, percent	1 low to 7 high
I_Z, percent	2 low to 5 high

The accuracy of measuring the weight and mass distribution of the model are believed to be within the following limits:

Weight, percent	± 1
Center-of-gravity location, percent $\bar{c}$	± 1
Moments of inertia, percent	± 5

Control settings were made with an accuracy of $\pm 1^\circ$.

TEST CONDITIONS

The conditions tested in the investigation of the longitudinal trim and tumbling characteristics of the model are listed in table II. Full-scale values of mass parameters for the loadings tested on the model and for various loading conditions of the airplane are given in table III. For all the tests, the landing gear was retracted and the cockpit closed.

As previously stated, lateral and longitudinal controls are combined into one pair of surfaces known as ailavators. Longitudinal control is obtained by deflection of the ailavators together, and lateral control is obtained by differential deflection of the ailavators. Hereinafter, ailavator deflections for longitudinal and lateral control will be referred to, for simplicity, as elevator and aileron deflections, respectively. For both the trim and tumble tests, in general, maximum up-, neutral-, and maximum down-elevator deflections were tested. The effects of lateral and directional controls were not determined for the trim and tumble tests because the model was free to rotate only about the pitch axis during trim tests, and spin-tunnel experience has indicated that lateral and directional controls have very little effect on model tumbling tendencies.

The normal maximum elevator deflections used in the tests were 30° up and 20° down. Lateral and directional controls were neutral for all tests. The speed brakes were deflected 35° up and 35° down when open.

RESULTS

The coefficients of lift, drag, and pitching moment for the model for various center-of-gravity positions in the clean condition and also with the slats extended are presented in figures 9 to 11. The results of the longitudinal trim tests are presented in table IV. The results of the dynamic tumble tests are shown in table V, and the results of tests to determine the parachute requirements for emergency use in terminating a tumble are presented in table VI. Table VII shows the centripetal and angular accelerations acting on the airplane and on the pilot at various angles of attack during a tumble of the XF7U-1 airplane. A comparison of the longitudinal stability characteristics of the 0.057-scale model with those of larger models at higher Reynold's numbers is shown on figures 12 and 13 for the clean condition and with slats extended, respectively.

Interpretation of Tumble Results

Comparison between model and airplane tumble results cannot be made as there exist no full-scale tumbling data. In applying the model results to the full-scale airplane, however, assuming no scale effect, the following interpretation has been placed on the results from the different methods of launching.

If the model tumbles when launched either with or without initial pitching rotation, it is taken as an indication that the corresponding airplane could tumble, although the airplane probably would be more likely to tumble if the model starts tumbling when launched with no pitching rotation. If the rotation stops after being launched with initial pitching rotation, the results are interpreted to mean that the corresponding airplane will not start tumbling.

Unpublished results indicate that the tumbling characteristics of a model are directly affected by some function of the static longitudinal stability characteristics of the model. It is believed, therefore, that a comparison of the general static longitudinal stability characteristics of the 0.057-scale model with those of larger models at higher Reynold's numbers should give some indication of the scale effect existent in the tumble tests. Comparison of the general slopes of the C_m against C_L curves, for the clean condition, is given in figure 12 and shows agreement through a large range of Reynold's number. It is believed, therefore, that the tumble results of the 0.057-scale model in the clean condition may be considered as directly applicable to the airplane. For the slat-extended configuration, an exact comparison of static-stability characteristics is not possible. A comparison of C_m against C_L is given, however, in figure 13 between a 0.057-scale model with 54-percent-semispan outboard slats extended and a 0.145-scale model (see reference 3)

with both 49.2-percent-semispan outboard slats and the 29-percent-semispan inboard slats extended (the slat configuration to be used on the airplane). These curves show similar inflections but indicate that the general slope of the curve for the 0.057-scale model with slats extended is representative of the larger scale results at a center-of-gravity position somewhat rearward of that of the 0.057-scale tests. It is believed, therefore, that the tumble results of the 0.057-scale model with slats extended may be considered applicable to the airplane for a somewhat more rearward center-of-gravity position, and therefore the model results may be considered as somewhat conservative.

DISCUSSION

Longitudinal Trim Characteristics

The results of both the static force tests (figs. 9 and 10) and the free-to-pitch longitudinal trim tests (table IV) show that the model did not trim at any unusual or uncontrolled angles of attack and that the elevators provided effective control over any trim attitude the model assumed. The results indicate satisfactory longitudinal stability above the stall and even up to 90° angle of attack. In the longitudinal trim tests, the model oscillated (short-period oscillations) through a small range of angle of attack for both maximum up and down elevator deflections, but it is believed that these oscillations were a result of testing technique inasmuch as free-flight-tunnel tests (see reference 4) indicated no such oscillations.

Tumble Characteristics

The results of the tumble tests (table V) show that with the center of gravity in the normal location (16.7 percent $\bar{c}$), the model could not be made to tumble by any method of launching employed and would recover instantaneously when launchod with initial pitching rotation and dive with no oscillations in pitch. With a center-of-gravity location of 22.6 percent $\bar{c}$, the results indicated that the model would not tumble, but the time required for the forced pitching rotation to damp out was noticeably greater than for the original condition. With a center-of-gravity location of 24 percent $\bar{c}$ (the most rearward indicated as possible on the airplane), the model still would not tumble when launched with initial pitching rotation but the time required for damping of the forced pitching rotation was further increased. Extending the slats when the center of gravity was at 22.6 percent $\bar{c}$ had no effect; however, with a center-of-gravity location of 24 percent $\bar{c}$, extending the slats when the elevators were deflected fully up caused the model to tumble when launched with positive pitching rotation. Figure 14 is a reproduction of a motion-picture record of this tumbling motion. When launched from a simulated whip stall or partial recovery from a whip stall with these same loadings and configurations, the model would not

tumble. This indicates that some external force, such as a strong gust, would probably be required to start the airplane tumbling. The longitudinal stability characteristics of the model in both the clean and slats-extended configurations with the center of gravity located at 22.6 percent $\bar{c}$ and 24 percent $\bar{c}$ are presented in figure 11. Figure 11 shows that for the condition of tumble (c.g. at 24 percent $\bar{c}$, slats extended) a somewhat more unstable slope of the pitching-moment curve was obtained than for the condition of no tumble (c.g. at 22.6 percent $\bar{c}$, slats extended). Either case with slats extended indicates less stable characteristics than those for the clean condition. As previously indicated, figure 12 shows that the longitudinal stability of the 0.057-scale model with 54-percent-semispan outboard slats extended and with the center of gravity at 24 percent $\bar{c}$ is somewhat less than the stability of a 0.145-scale model of the same airplane with outboard and inboard slats, and it is therefore believed that the tumble results with slats extended are somewhat conservative. The speed brakes had no effect on the tumble characteristics of the model. The results indicate that should the airplane tumble for any of the conditions tested on the model, recovery can be effected rapidly by immediate full reversal of the elevators against the rotation.

Tumble-Recovery Parachute Tests

For tests to determine the parachute requirements for emergency use in terminating a tumble (table VI), wing-tip parachutes of 8.77 and 4.24 feet (full scale) in diameter were used in conjunction with towline lengths of 25 feet and 13.6 feet (full scale), respectively. The center of gravity was located at 24 percent of the mean aerodynamic chord and the slats were extended (the configuration for which the model would tumble). Results indicated that the simultaneous opening of either the two small parachutes (4.24 feet in diameter) or the two large parachutes (8.77 feet in diameter) would terminate the tumble rapidly. The smaller size parachute did not effect recovery from the tumble so rapidly as did the larger parachutes. When either the small or the large parachutes were opened singly, the model would recover from the tumble but went into a motion which appeared to be start of a spin. The small parachutes had a tendency to collapse in the wing wake indicating that the towline length was shorter than desirable. As indicated in reference 5, towlines should be of sufficient length to assure efficient operation of the parachutes but not so long as to become fouled with parts of the airplane. Spin-tunnel experience has indicated that for tumble recovery, parachutes should be attached at the wing tip to avoid tangling of the towline about the wing and, further, that the parachute be attached as far rearward on the tip as possible to obtain the maximum moment arm. It is further indicated that positive ejection of the parachutes should be used, and it is felt that the parachutes should be opened when the airplane is approaching a nose-down diving

attitude such that the parachutes will be washed rearward and thereby further reduce the possibility of the towlines becoming entangled with the wing. The parachutes should be released as soon as the tumbling motion has ceased.

Acceleration in a Tumble

An analysis of the motion of the XF7U-1 model during a tumble indicated that the acceleration varied in magnitude and direction during the course of one revolution of a tumble which is due primarily to the change in rate of rotation of the airplane about its center of gravity. The results of this analysis (table VII) indicate that the most critical value of the component of acceleration directed along the long axis of the pilot a' may be of the order of $-3g$ and the component normal to the long axis of the pilot a'' will always tend to force the pilot forward in the cockpit and may be as high as 14g. However, the effects of gravity (1 g) must be added to these results in order to obtain the true acceleration to which the pilot will react physiologically. Inspection of figure 6 and table VII indicates that the position of the pilot when these values of a' and a'' occurred was such that the effect of gravity will increase a' to $-4g$ and a'' to 15g. The centripetal acceleration due to rotation about the center of gravity constitutes the larger portion of the total resultant acceleration and is due primarily to the great distance at which the pilot is located from the center of gravity. Little is known about rapid repetition of exposure to short-period accelerations, but reference 6 indicates that a continued negative acceleration of 3g may cause symptoms of concussion of the brain and that negative accelerations of 5g may result in massive cerebral hemmorhage and possibly death. Reference 6 further indicated that continued accelerations normal to the long axis of the pilot are not well tolerated above 12g. Thus it appears that the accelerations in a tumble may be dangerous to the pilot and, therefore, action should be taken to terminate the tumble immediately upon its inception.

Pilot-Escape Tests

When a dummy pilot was released from the top of the canopy into the free stream during a tumble, it was observed to clear all parts of the model in each of several attempts by a large margin. From these results, it appears that the pilot will not be struck by the airplane if it becomes necessary that he leave during a tumble. However, the accelerations acting on the pilot indicate that the pilot may experience difficulty in climbing out of the cockpit and may require aid from an ejection-seat arrangement.

CONCLUSIONS AND RECOMMENDATIONS

Based on results of longitudinal trim and tumble tests of a 0.057-scale model of the Chance Vought XF7U-1 airplane, the following conclusions regarding the trim and tumble characteristics of the airplane have been drawn:

1. The airplane will not trim at any unusual or uncontrolled angles of attack.

2. The airplane will not tumble with the center of gravity located forward of 24 percent of the mean aerodynamic chord. When the center of gravity is located at 24 percent of the mean aerodynamic chord and slats are extended and elevators are deflected full up, the airplane may tumble if given an external positive pitching moment.

3. The tumbling motion obtained will be readily terminated by deflecting the elevators full down so as to oppose the rotation.

4. The accelerations encountered during an established tumble may be dangerous to the pilot and, therefore, action should be taken to terminate a tumble immediately upon its inception.

5. Simultaneous opening of two wing-tip parachutes having diameters of 4 feet or larger and having drag coefficients of approximately 0.7 will effectively terminate the tumble.

6. Model results indicate that the pilot will not be struck by the airplane if it becomes necessary to leave the airplane during a tumble. The pilot may require aid from an ejection-seat arrangement.

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TABLE I.– DIMENSIONAL CHARACTERISTICS OF THE

CHANCE VOUGHT XF7U-1 AIRPLANE

Length, over all, ft	36.44
Wing:	
Span, ft	38.67
Area, sq ft	496
Aspect ratio	3.01
Root chord, in.	192
Tip chord, in.	116
Mean aerodynamic chord, in.	157
L.E. $\bar{c}$ rearward L.E. root chord, in.	83.56
Taper ratio	0.60
Incidence (constant), deg	0
Dihedral, deg	0
Sweepback of quarter-chord line. deg	35
Airfoil section	CVA 4-(00)-(12)-(1.1)(1.0)
Ailavator:	
Span, percent b/2	47.2
Location of inboard end 2y/b	.491
Location of outboard end 2y/b	.963
Total area, sq ft	54.4
Area rearward of hinge line, sq ft	53.0
Chord, percent c:	
Inboard station	22.4
Outboard station	29.2
Vertical tail:	
Height, ft	9.24
Total area, sq ft	122.4
Rudder area, sq ft	32.0
Aspect ratio	1.31
Location of vertical tail, 2y/b	.65
Sweepback quarter-chord line, deg	45
Airfoil section	CVA special
Speed brakes (split type):	
Span, percent b/2	23.8
Slats:	
Span, percent b/2	54.4

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TABLE II.- CONDITIONS TESTED IN THE INVESTIGATION OF TRIM AND TUMBLING CHARACTERISTICS OF THE 0.057-SCALE MODEL OF THE CHANCE VOUGHT XF7U-1 AIRPLANE

No.	Change from original clean configuration	Center-of-gravity location, percent $\bar{c}$	Parachute attached to	Data presented on table
Longitudinal trim tests				
1	None	16.3	None	IV
2	Speed brakes open	16.3	-------do-------	IV
3	Speed brakes open, slats extended	16.3	-------do-------	IV
4	Slats extended	16.3	-------do-------	IV
5	---------do----------	26.3	-------do-------	IV
6	Speed brakes open, slats extended	26.3	-------do-------	IV
7	None	26.3	-------do-------	IV
Tumble tests				
8	None	16.7	None	V
9	--------do-----------	24.0	-------do-------	V
10	Speed brakes open	24.0	-------do-------	V
11	Slats extended	24.0	-------do-------	V
12	--------do-----------	22.6	-------do-------	V
13	None	22.6	-------do-------	V
14	Slats extended, two parachutes installed	24.0	One each wing tip 75 percent c	VI
15	Slats extended, one parachute installed	24.0	Right wing tip 75 percent c	VI

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[redacted]

TABLE III.– MASS CHARACTERISTICS AND INERTIA PARAMETERS FOR VARIOUS LOADINGS POSSIBLE ON THE CHANCE VOUGHT XF7U-1 AIRPLANE AND FOR THE LOADINGS OF THE 0.057-SCALE MODEL AS TUMBLE-TESTED

[Model values are presented in terms of full-scale values]

Loading	Weight (lb)	Center-of-gravity location		Airplane relative density (μ)		Moments of inertia about center of gravity (slug-ft^2)			Mass parameters		
		$x/\bar{c}$	$z/\bar{c}$	Sea level	15,000 feet	I_X	I_Y	I_Z	$\frac{I_X - I_Y}{mb^2}$	$\frac{I_Y - I_Z}{mb^2}$	$\frac{I_Z - I_X}{mb^2}$
Airplane values											
Normal (combat loading)	14,485	0.163	−0.003	9.86	15.68	13,265	23,646	36,149	-154×10^{-4}	-186×10^{-4}	340×10^{-4}
Most rearward center of gravity (7.6 percent $\bar{c}$ rearward of normal)	13,505	.239	−.004	9.19	14.61	18,171	23,950	41,405	-92×10^{-4}	-278×10^{-4}	370×10^{-4}
Model values											
Normal	14,517	0.167	−0.004	9.89	15.72	13,250	22,943	35,021	-144×10^{-4}	-179×10^{-4}	323×10^{-4}
Center of gravity 7.7 percent $\bar{c}$ rearward of desired normal	14,484	.24	−.003	9.87	15.68	13,250	23,810	35,887	-157×10^{-4}	-180×10^{-4}	337×10^{-4}
Center of gravity 6.3 percent $\bar{c}$ rearward of desired normal	14,484	.226	−.003	9.86	15.68	13,437	25,412	37,640	-178×10^{-4}	-182×10^{-4}	360×10^{-4}

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TABLE IV.— RESULTS OF LONGITUDINAL TRIM TESTS OF THE 0.057-SCALE MODEL

OF THE CHANCE VOUGHT XF7U-1 AIRPLANE

[Center-of-gravity location as indicated; slats and speed brakes as indicated; dynamic pressure $q = 2.6$ lbs per sq ft]

Elevator setting (deg)	Speed brakes	Slats	Center-of-gravity location, percent $\bar{c}$	Trim angles of attack, α	Remarks
−30	Closed	Retracted	16.3		Oscillated between 11 and 25
−20	--do--	---do----	16.3		Oscillated between 16 and 21
−18	--do--	---do----	16.3	15	Oscillated slightly
−15	--do--	---do----	16.3	13	Oscillated slightly
−10	--do--	---do----	16.3	12	
−2	--do--	---do----	16.3	6	
0	--do--	---do----	16.3	2	
2	--do--	---do----	16.3	−4	
10	--do--	---do----	16.3	−11	
15	--do--	---do----	16.3	−13	
20	--do--	---do----	16.3		Oscillated between −12 and −18
−30	Open	---do----	16.3		Oscillated between 2 and 27
0	--do--	---do----	16.3	2	
20	--do--	---do----	16.3		Oscillated between −5 and −26
−30	--do--	Extended	16.3		Oscillated between 14 and 26
0	--do--	---do----	16.3	−1	
20	--do--	---do----	16.3		Oscillated between −8 and −21
−30	Closed	---do----	16.3	21	
0	--do--	---do----	16.3	0	
20	--do--	---do----	16.3	−15	
−30	--do--	---do----	26.3	32	
0	Closed	Extended	26.3	15, −14	
20	--do--	---do----	26.3	−35	
−30	Open	---do----	26.3	30	
0	--do--	---do----	26.3		Oscillated between 13 and 19
0	--do--	---do----	26.3		Oscillated between −6 and −15
20	--do--	---do----	26.3	−34	
−30	Closed	Retracted	26.3	25	
−2	--do--	---do----	26.3		Oscillated between 24 and 26
0	--do--	---do----	26.3	14, −11	
2	--do--	---do----	26.3	13, −11	
20	--do--	---do----	26.3	−20	

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TABLE V.— TUMBLING CHARACTERISTICS OF THE 0.057-SCALE MODEL OF THE CHANCE VOUGHT XF7U-1 AIRPLANE

[Center-of-gravity location as indicated; tunnel airspeed was 168 ft per sec; full scale]

Loading	Configuration	Method of launching	Behavior of model		
			Stick full back	Stick neutral	Stick full forward
Normal center of gravity 16.7 percent $\bar{c}$	Clean	Positive initial rotation	D	C, E	D
--------do-------	-----do-------	Negative initial rotation	D	E	E
Center of gravity 24 percent $\bar{c}$	-----do-------	Positive initial rotation	E	B	C
--------do-------	-----do-------	Negative initial rotation	C	C	F
--------do-------	-----do-------	Released from nose up, simulated whip stall	C	—	—
--------do-------	-----do-------	Released from nose horizontal, simulated recovery from whip stall	—	B	—
--------do-------	Slats extended	Positive initial rotation	A, F	C, E	C
--------do-------	------do-------	Negative initial rotation	C	C	D
--------do-------	------do-------	Released from nose up, simulated whip stall	C	—	—
--------do-------	------do-------	Released from nose horizontal, simulated recovery from whip stall	D	—	—
Center of gravity 24 percent $\bar{c}$	Speed brakes open	Positive initial rotation	F	—	C
--------do-------	-----do-------	Negative initial rotation	C	—	—
Center of gravity 22.6 percent $\bar{c}$	Slats extended	Positive initial rotation	B, C	C	—
--------do-------	Clean	--------do--------	C, E	C	—

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Key to behavior of model:

A – Continued to tumble.
B – Stopped tumbling, dived with undamped oscillations in pitch.
C – Stopped tumbling, dived with damped oscillations in pitch.
D – Stopped tumbling, dived with no oscillations in pitch.
E – Stopped tumbling, went into a spin.
F – Stopped tumbling, dived with oscillations in roll, pitch, and yaw.

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TABLE VI.– EFFECTIVENESS OF PARACHUTES IN PRODUCING RECOVERY FROM ESTABLISHED TUMBLES OF THE 0.057-SCALE MODEL OF THE CHANCE VOUGHT XF7U-1 AIRPLANE

[Center of gravity located 24 percent $\bar{c}$; elevators deflected full up; slats extended; speed brakes closed; towline attached to wing tip, 75 percent c; tunnel airspeed 168 feet per second, full scale; drag coefficient of parachutes approximately 0.68; model launched with positive initial pitching rotation; recovery attempted by opening parachutes as indicated]

Diameter of parachute (full scale) (ft)	Towline length (full scale) (ft)	Recovery attempted by	Turns for recovery after parachutes opened	Remarks
8.3	25	Opening two parachutes, one attached to each wing tip	$\frac{1}{4}$, $\frac{1}{4}$	After recovery from tumble, model dived with no oscillations
4.4	13.6	-------do---------	$\frac{1}{2}$, $\frac{3}{4}$, $1\frac{1}{2}$, $1\frac{3}{4}$	Sometimes parachutes would collapse in wing wake and reopen or become entangled with tip fairings; sometimes model would go into a spin after recovery
8.3	25	Opening parachute attached to right wing tip	$\frac{1}{2}$, $\frac{1}{2}$	After recovery from tumble, model went into a spin
4.4	13.6	-------do---------	$\frac{1}{4}$, 1	After recovery from tumble, model went into a spin

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TABLE VII.– ACCELERATIONS IN A TUMBLE OF AN 0.057-SCALE MODEL OF THE CHANCE VOUGHT XF7U-1 AIRPLANE

[Center-of-gravity located at 24 percent of the mean aerodynamic chord; slats extended; positive pitching rotation; rate of descent approximately 200 fps; pilot's head located at r = 13.4 ft from the center of gravity; all values are approximate]

Time, t (sec)	Angle of attack α (deg)	[1]Centripetal acceleration due to rotation about the center of gravity a_c (g units)	[1]Tangential acceleration due to angular acceleration about the center of gravity a_A (g units)	Component of acceleration directed through long axis of pilot a' (g units)	Component of acceleration normal to long axis of pilot a'' (g units)	Total resultant acceleration of the pilot's head a (g units)
0.033	31	7.7	-0.2	-1.6	-7.5	7.7
.098	48	7.4	-.6	-2.0	-7.1	7.4
.163	62	7.2	-1.0	-2.3	-6.9	7.2
.228	78	6.5	-1.2	-2.4	-6.1	6.6
.293	92	5.7	-1.5	-2.6	-5.3	5.9
.358	105	5.1	-1.6	-2.6	-4.7	5.3
.423	118	4.0	-1.8	-2.5	-3.6	4.4
.488	128	3.5	-1.8	-2.5	-3.1	4.0
.553	139	3.0	-2.0	-2.5	-2.6	3.6
.618	148	2.4	-2.0	-2.5	-1.9	3.0
.683	156	1.7	-2.1	-2.4	-1.2	2.7
.748	164	1.2	-2.0	-2.2	-.8	2.4
.813	172	.8	.8	.6	-1.0	1.1
.878	177	.8	2.0	1.8	-1.2	2.1
.943	-175	1.9	.8	.4	-2.0	2.1
1.008	-167	2.1	.6	.2	-2.2	2.2
1.073	-158	2.2	.7	.3	-2.3	2.3
1.138	-148	2.6	1.3	.8	-2.8	2.9
1.203	-138	5.4	1.9	.9	-5.6	5.7
1.268	-126	3.9	2.5	1.8	-4.3	4.6
1.333	-112	10.6	3.0	.9	-11.1	11.1
1.398	-98	13.7	3.3	.7	-13.8	13.8
1.463	-83	9.3	2.1	.3	-9.7	9.7
1.528	-66	9.2	.0	-1.8	-9.0	9.2
1.593	-47	8.4	-1.3	-3.0	-8.0	8.5
1.658	-29	7.9	-.7	-2.2	-7.6	7.9
1.723	-14	7.9	-.5	-2.0	-7.6	7.9

[1]Values obtained from figure 8.

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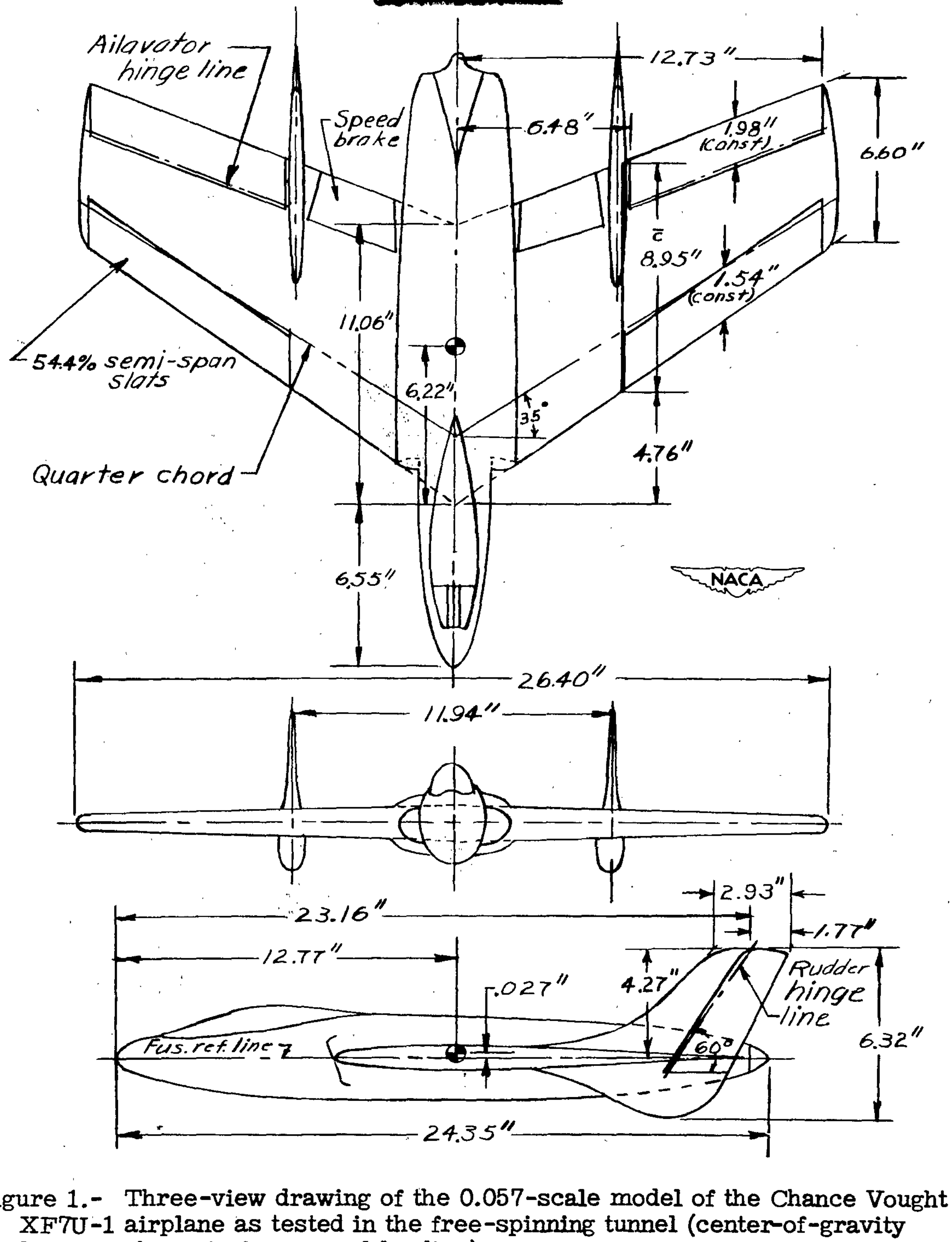

Figure 1.- Three-view drawing of the 0.057-scale model of the Chance Vought XF7U-1 airplane as tested in the free-spinning tunnel (center-of-gravity location shown is for normal loading).

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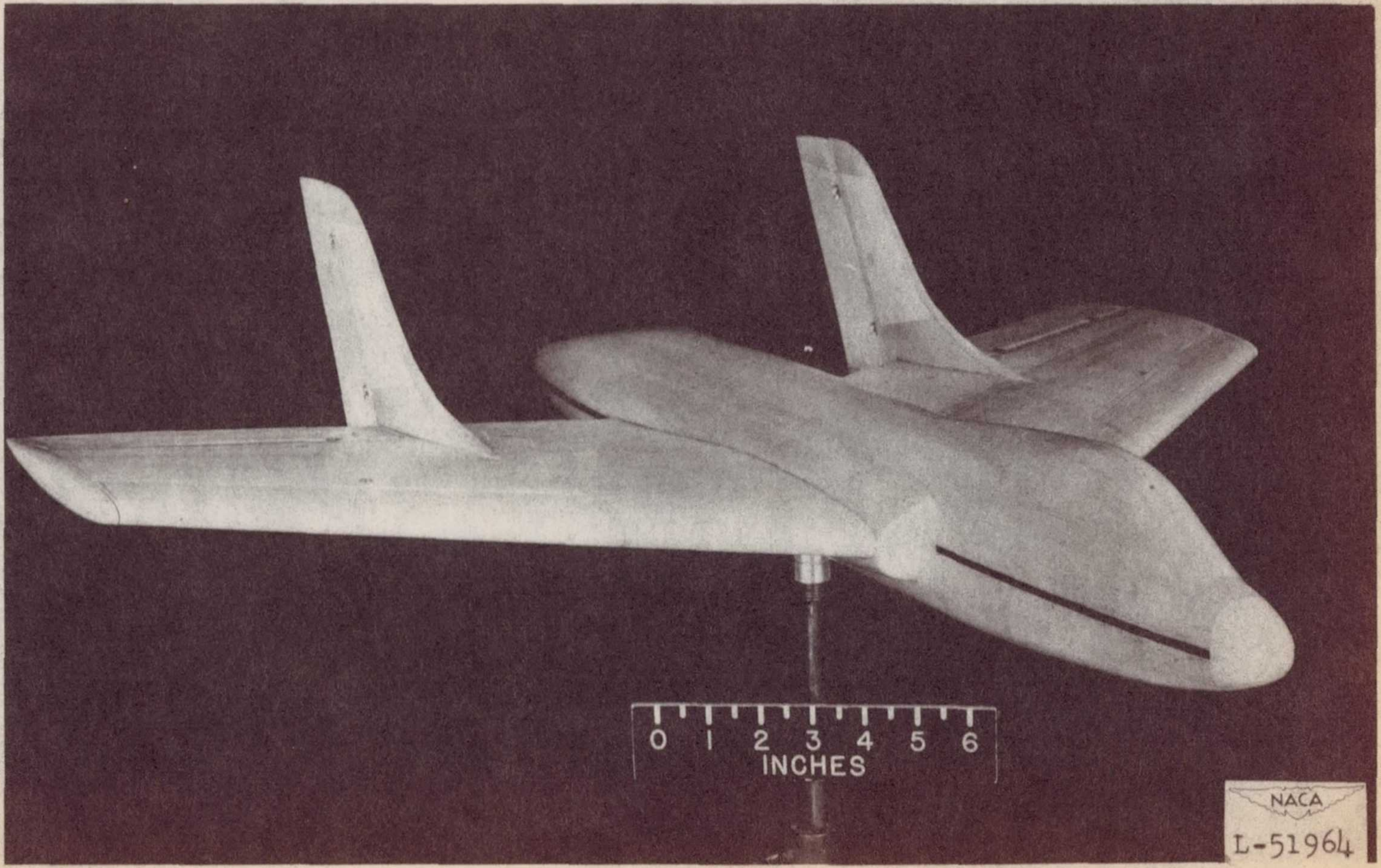

Figure 2.- A 0.057-scale model of the Chance Vought XF7U-1 airplane as tested in the Langley 20-foot free-spinning tunnel in the clean configuration.

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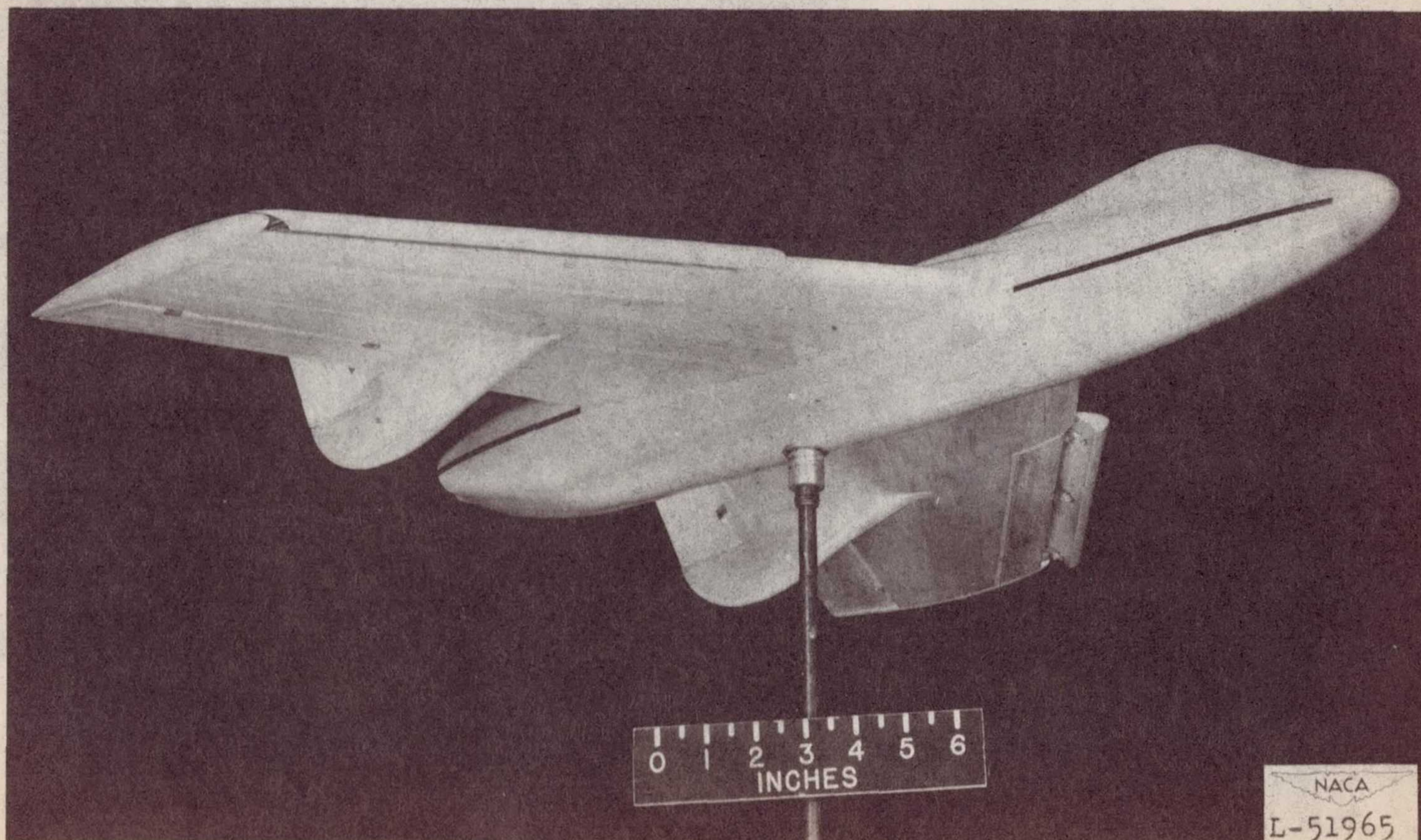

Figure 3.- A 0.057-scale model of the Chance Vought XF7U-1 airplane as tested in the Langley 20-foot free-spinning tunnel with slats extended.

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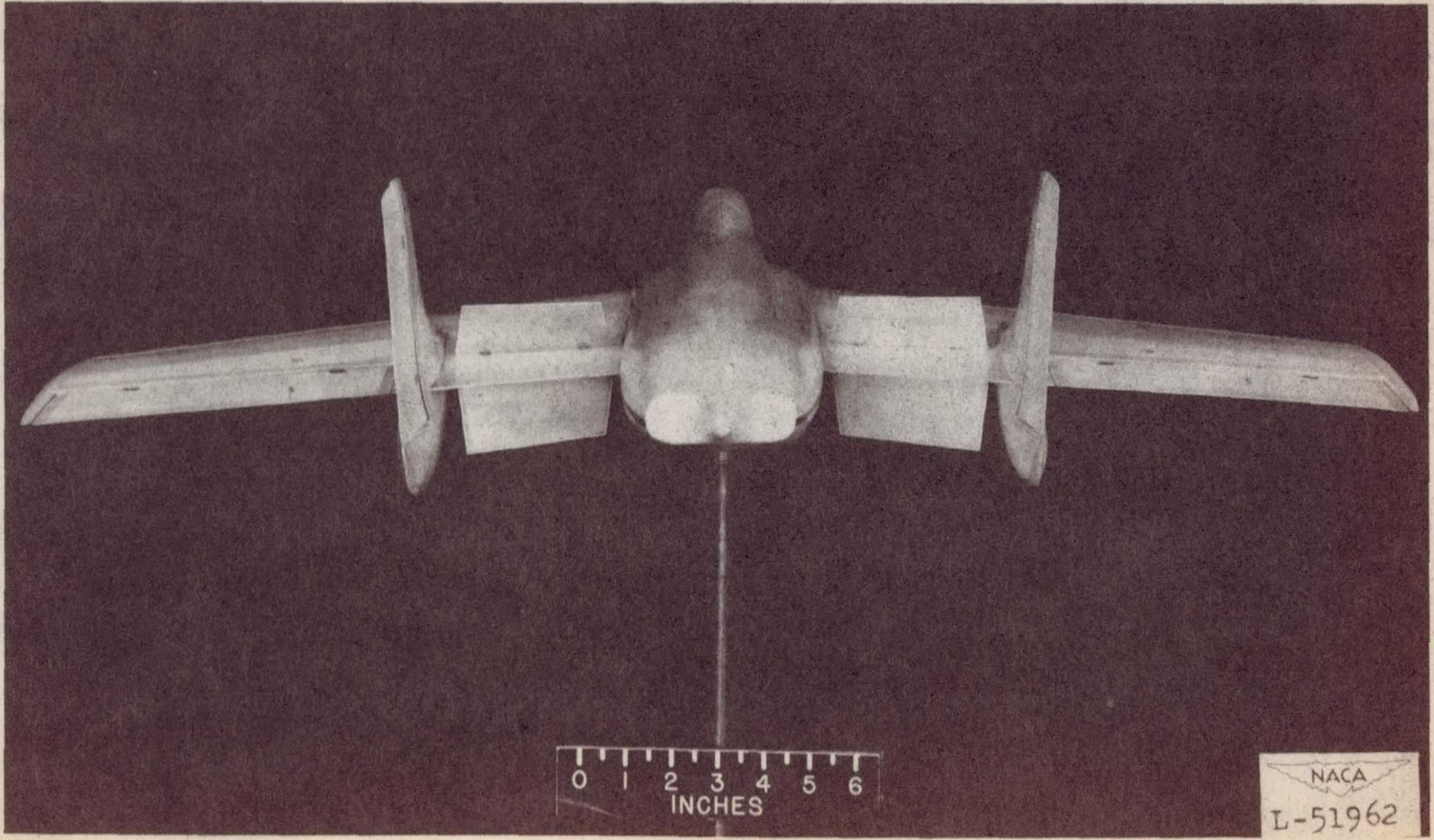

Figure 4.- A 0.057-scale model of the Chance Vought XF7U-1 airplane as tested in the Langley 20-foot free-spinning tunnel with speed brakes open.

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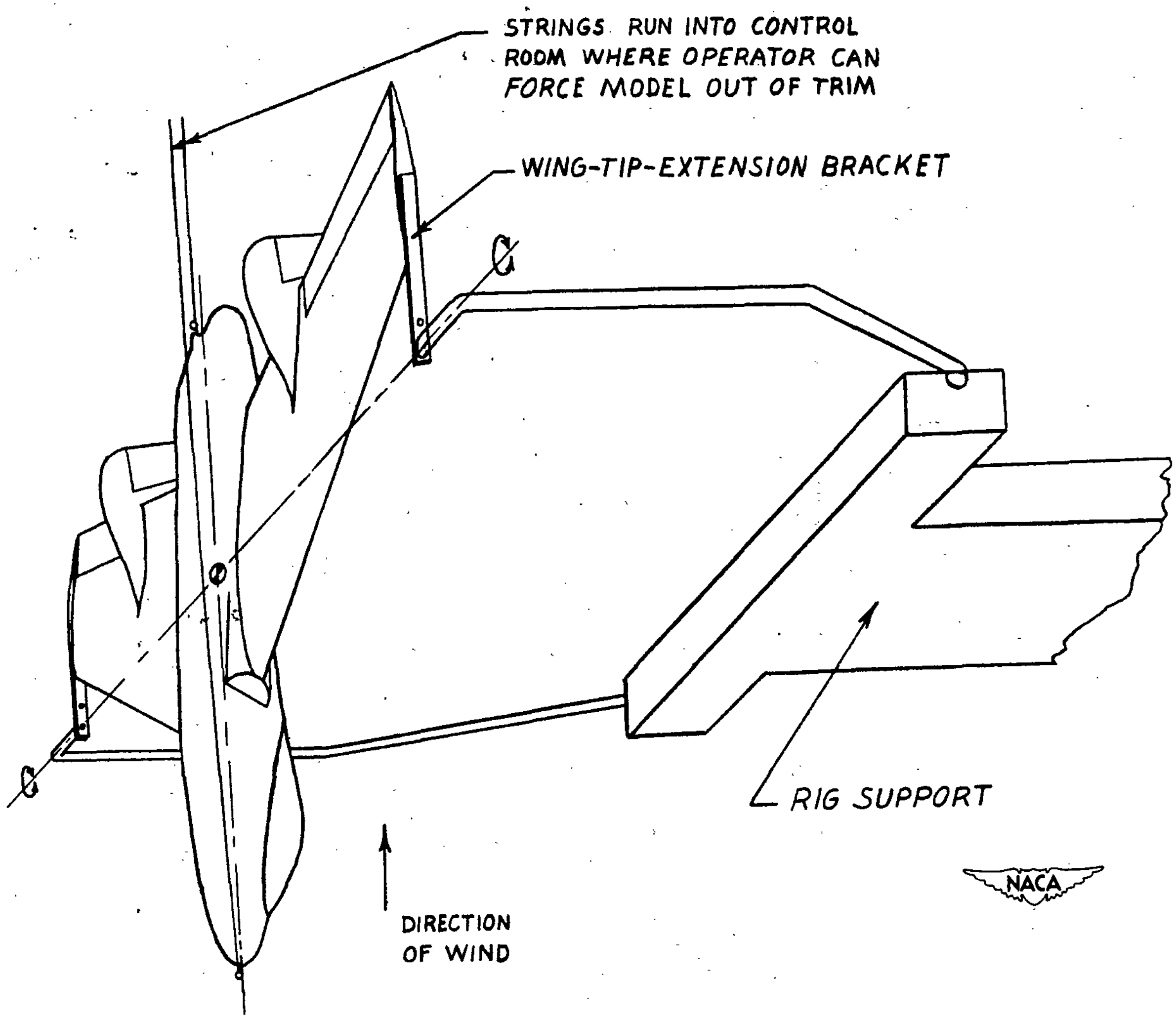

Figure 5.- Sketch showing the 0.057-scale model of the Chance Vought XF7U-1 airplane mounted on the trim test rig in the 20-foot free-spinning tunnel. Model shown in the clean condition.

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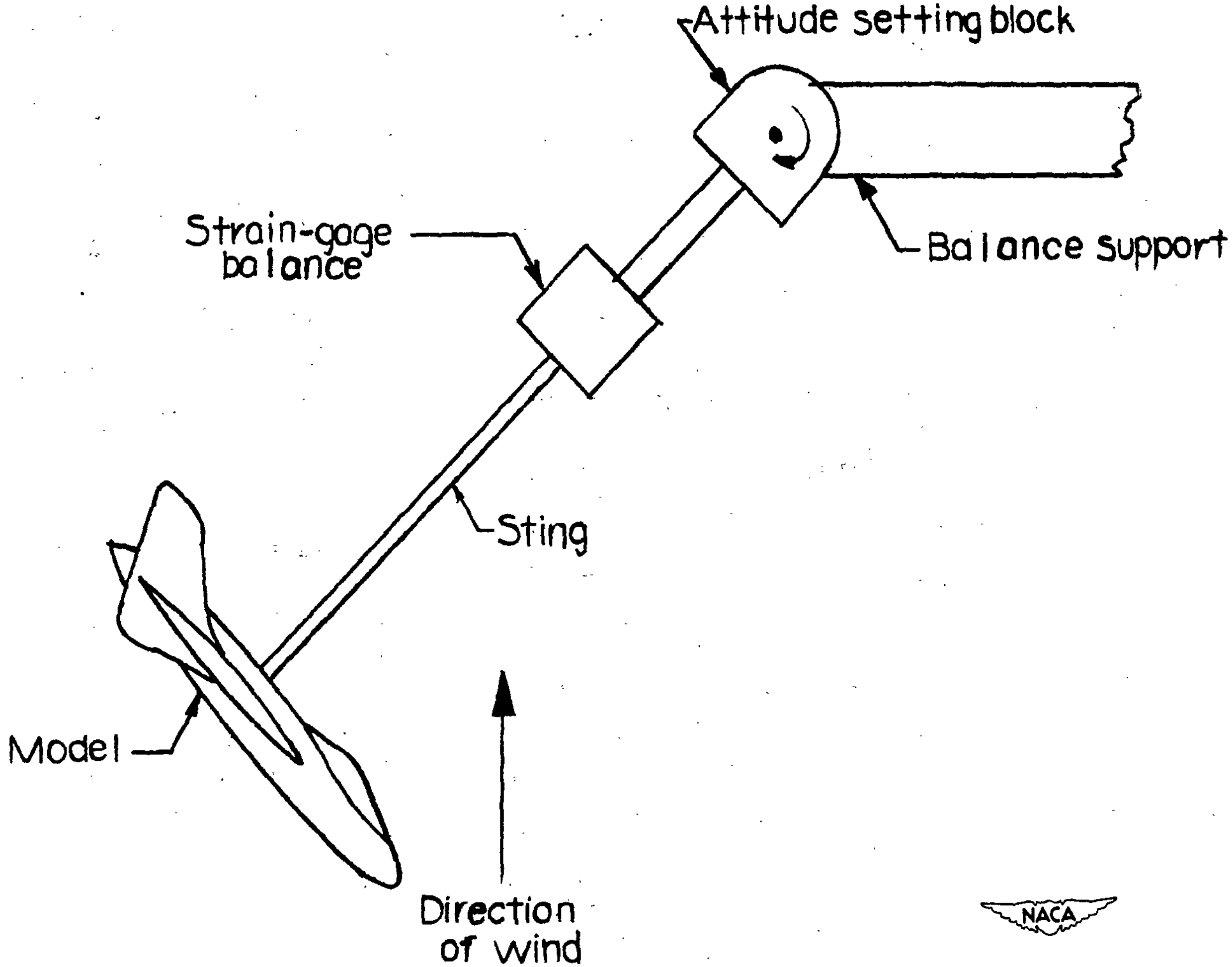

Figure 6.- Sketch showing model mounted on the strain-gage balance in the Langley 20-foot free-spinning tunnel.

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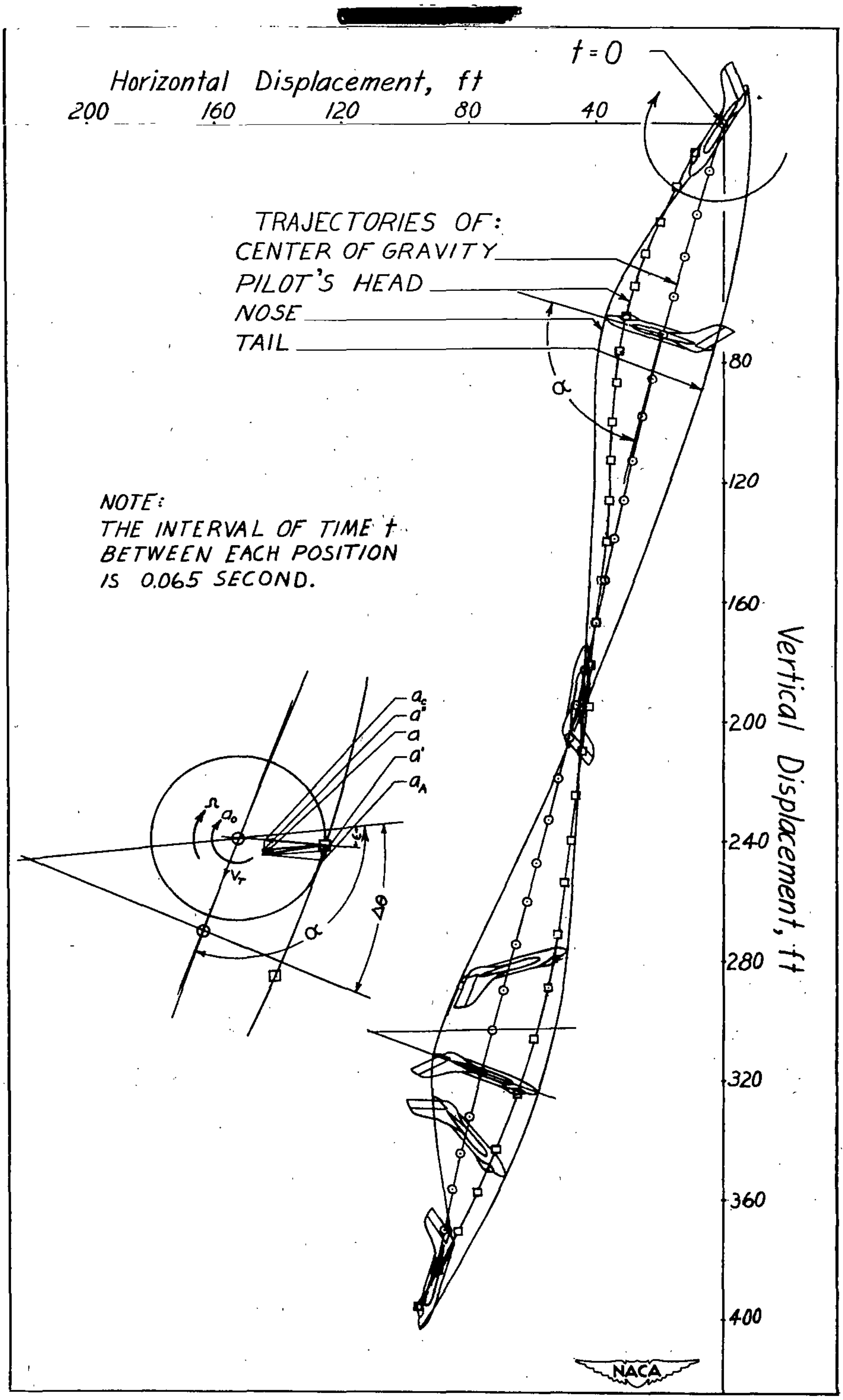

Figure 7.- Path of motion of the Chance Vought XF7U-1 airplane obtained from model data during a tumble. Center of gravity 24 percent mean aerodynamic chord. Slats extended; elevators full up.

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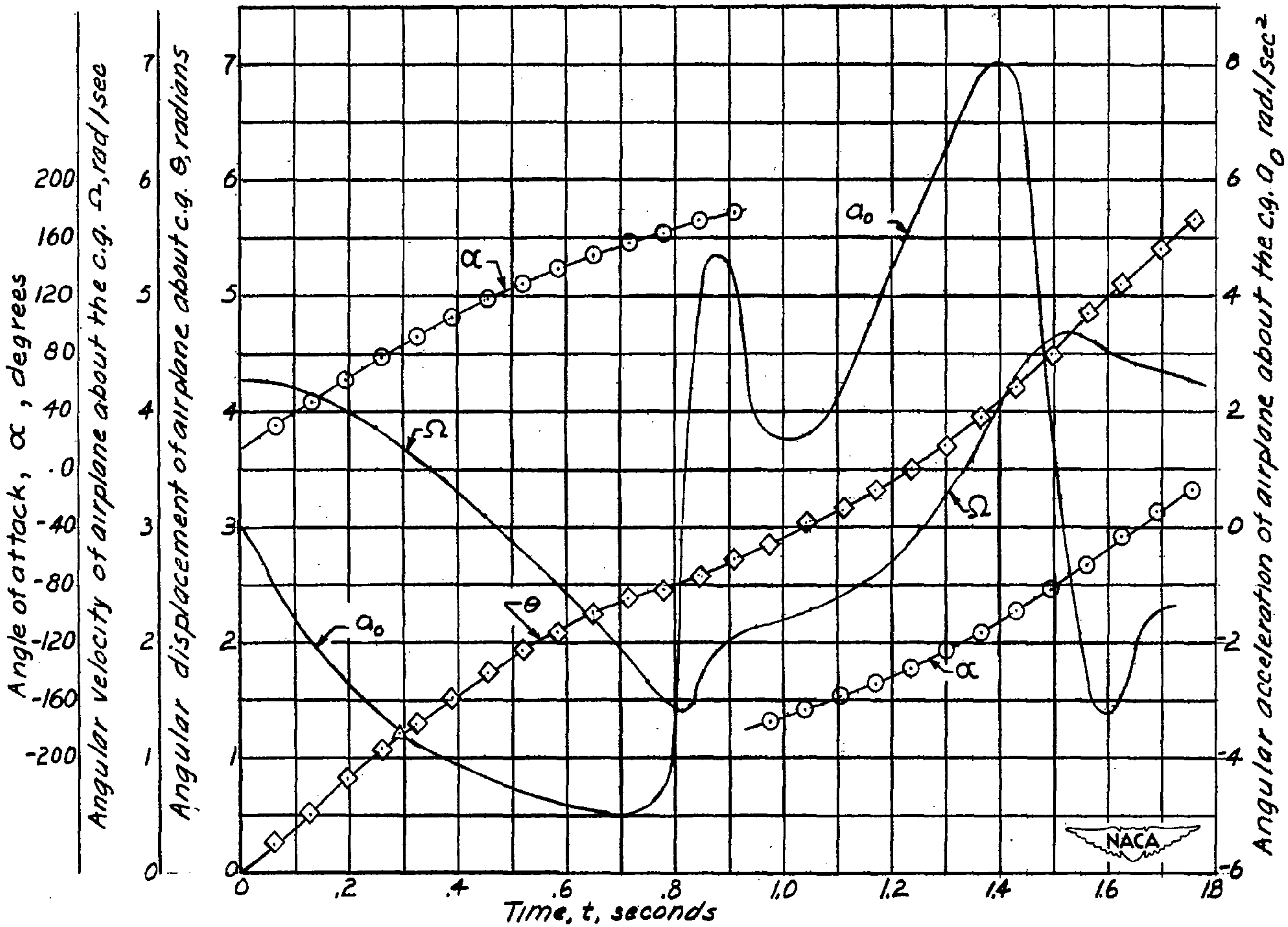

Figure 8.- Graphical determination of components of acceleration of pilot's head, which is located at γ (= 13.4) feet from the center of gravity, during a tumble of the 0.057-scale model of the Chance Vought XF7U-1 airplane.

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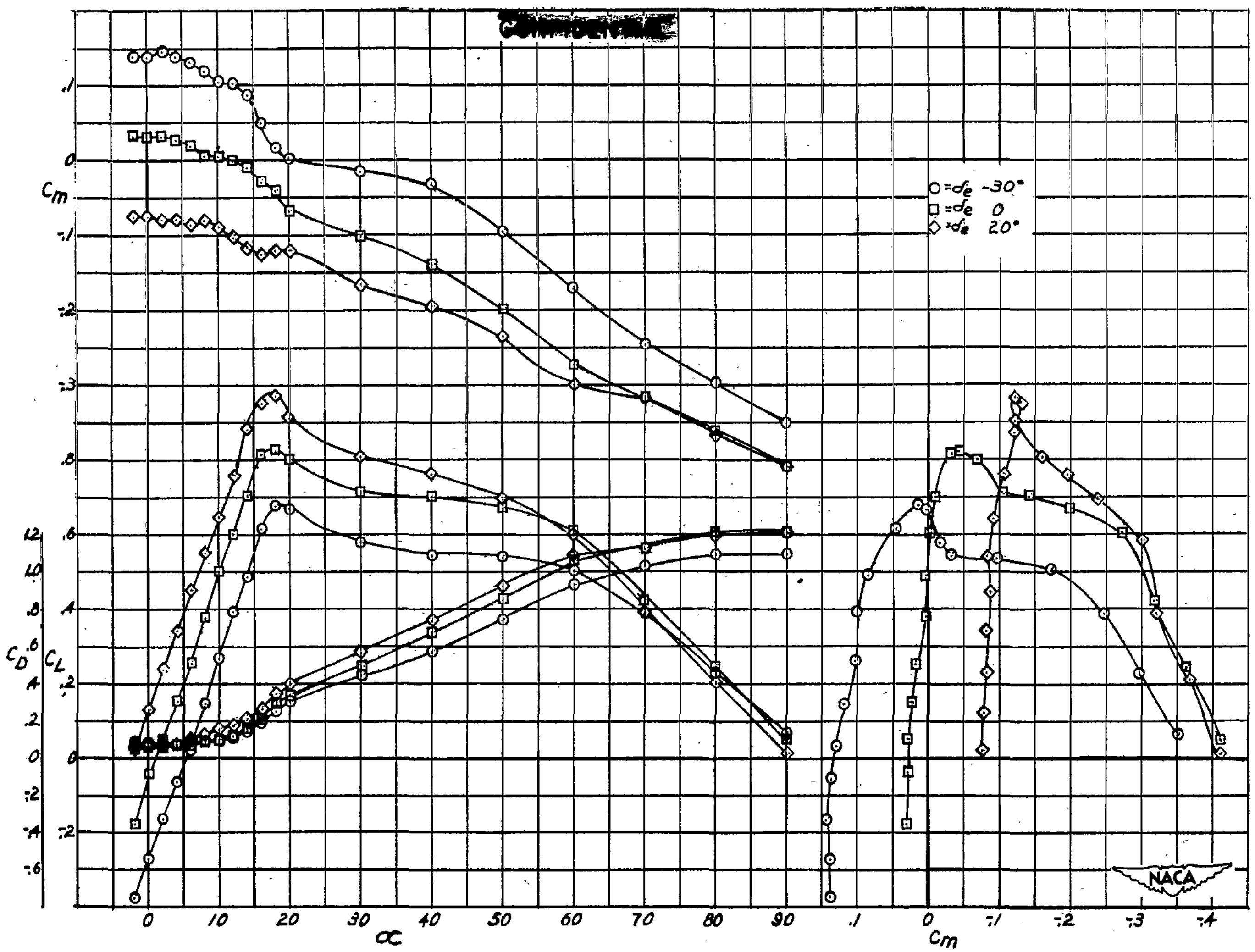

Figure 9.- Aerodynamic characteristics of the 0.057-scale model of the Chance Vought XF7U-1 airplane. Elevator deflection as indicated. Center of gravity located 16.3 percent mean aerodynamic chord; clean condition; $\psi = 0^{\circ}$.

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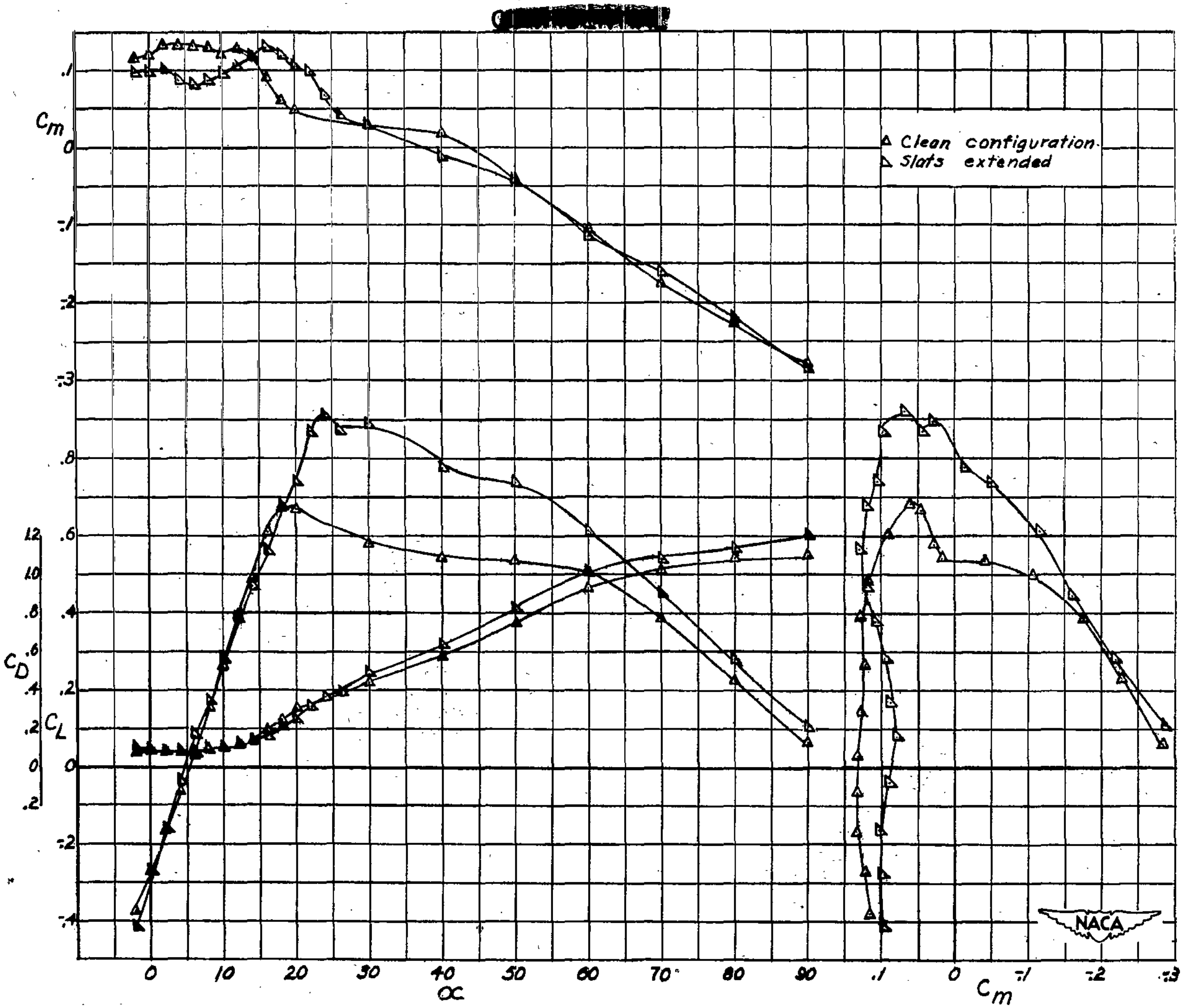

Figure 10.- Aerodynamic characteristics of the 0.057-scale model of the Chance Vought XF7U-1 airplane. Elevator deflection, -30°; slats as indicated; center of gravity located 22.6 percent mean aerodynamic chord; $\psi = 0°$.

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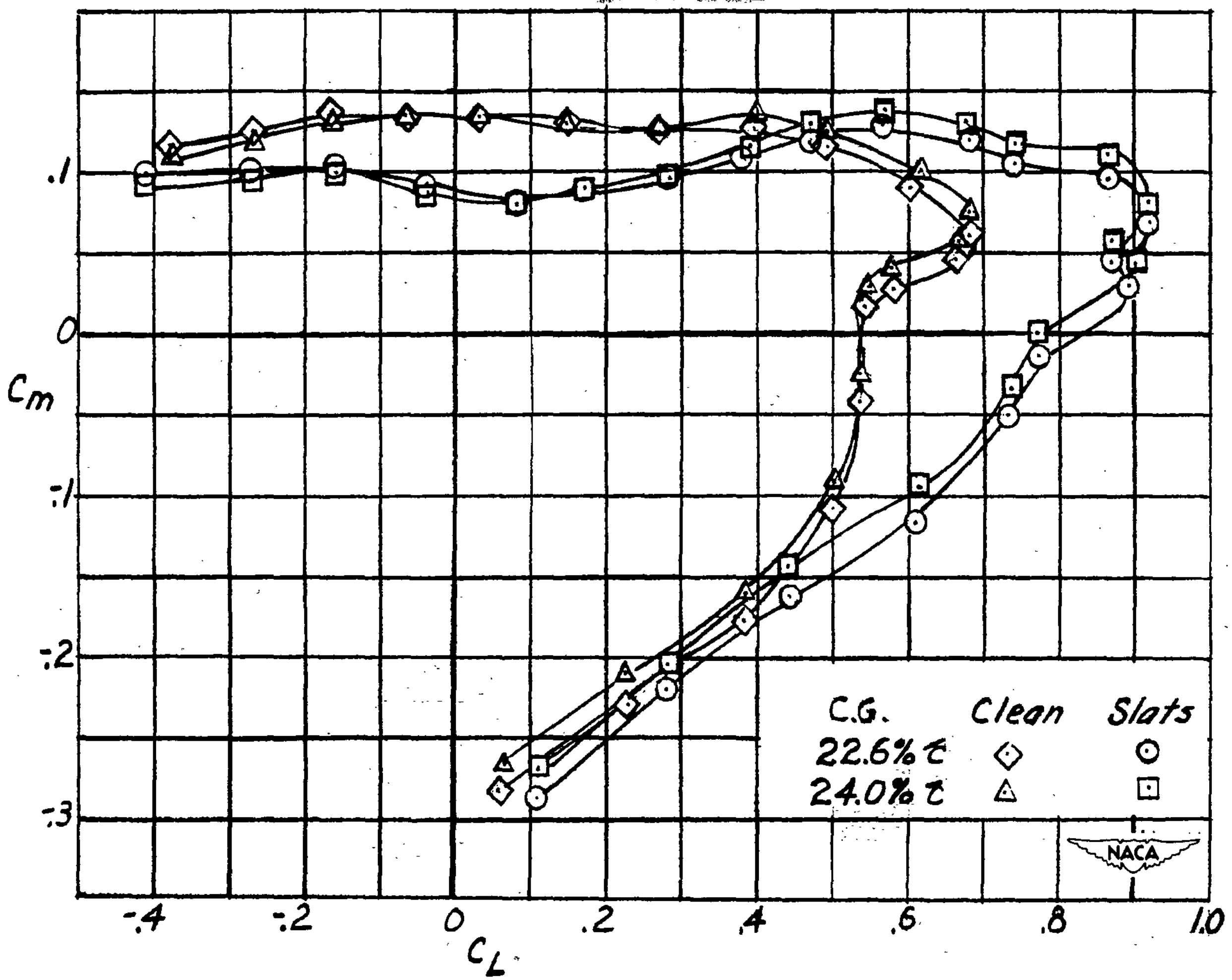

Figure 11.- Pitching-moment characteristics for an 0.057-scale model of the Chance Vought XF7U-1 airplane. Center-of-gravity location and configuration as indicated; $\delta_e = -30^{\circ}$; $\psi = 0^{\circ}$.

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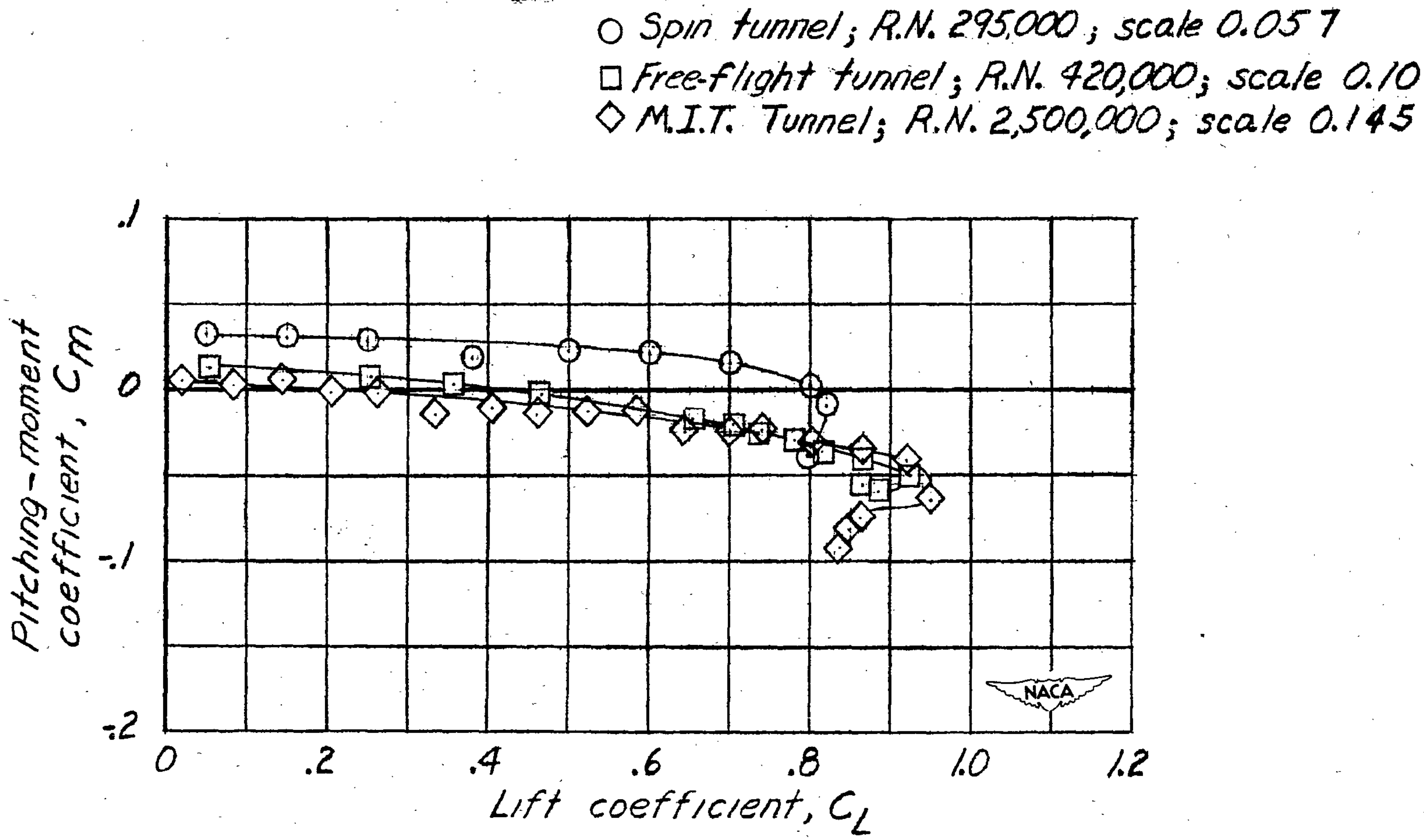

Figure 12.- Comparison of pitching-moment data for three scale models of the Chance Vought XF7U-1 airplane. Reynolds number as indicated; center of gravity located 20 percent $\bar{c}$; clean condition; $\delta_e = 0^{\circ}$.

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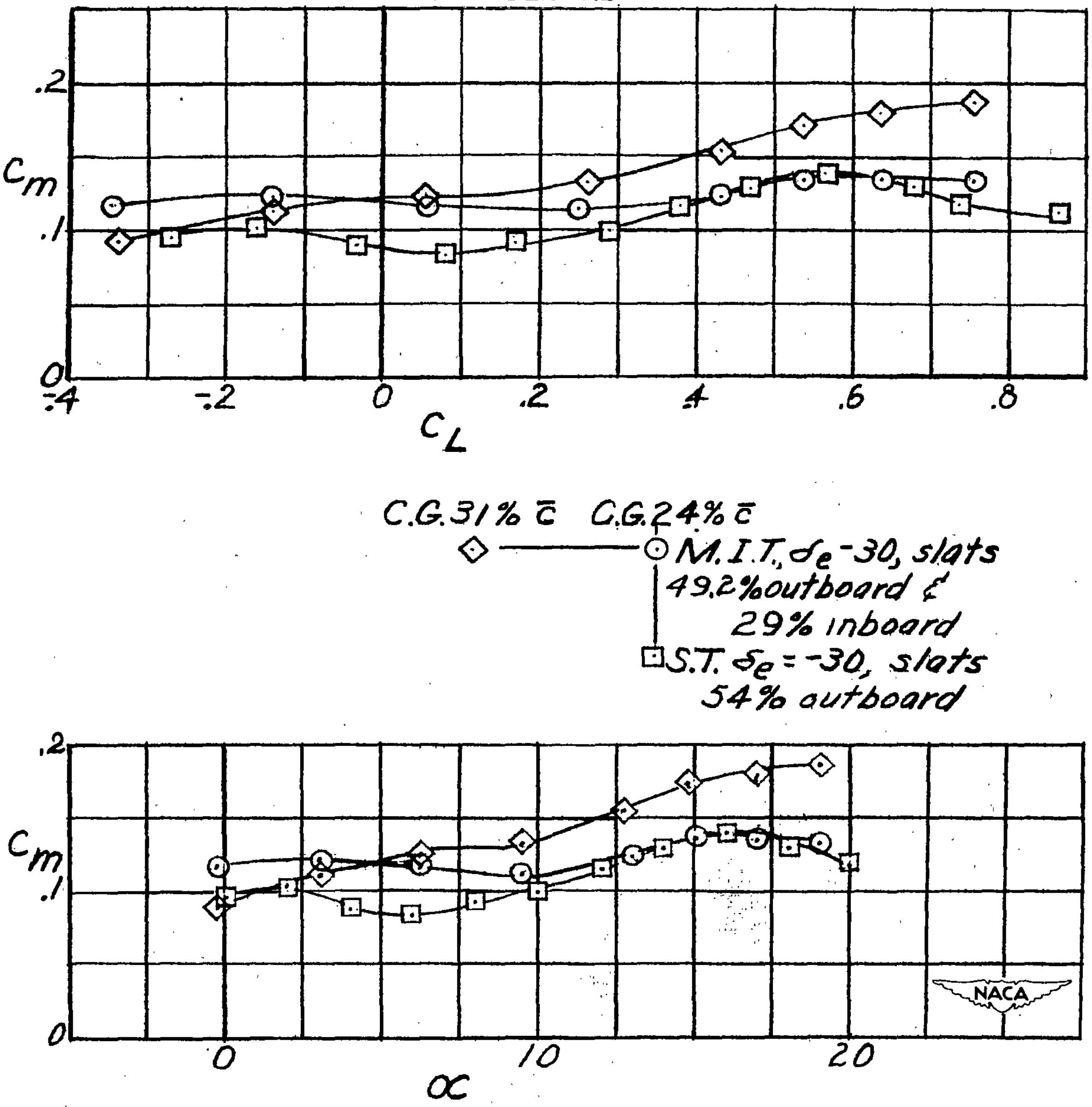

Figure 13.- Comparison of pitching-moment characteristics of the 0.057-scale model with an 0.145-scale model of the Chance Vought XF7U-1 airplane.

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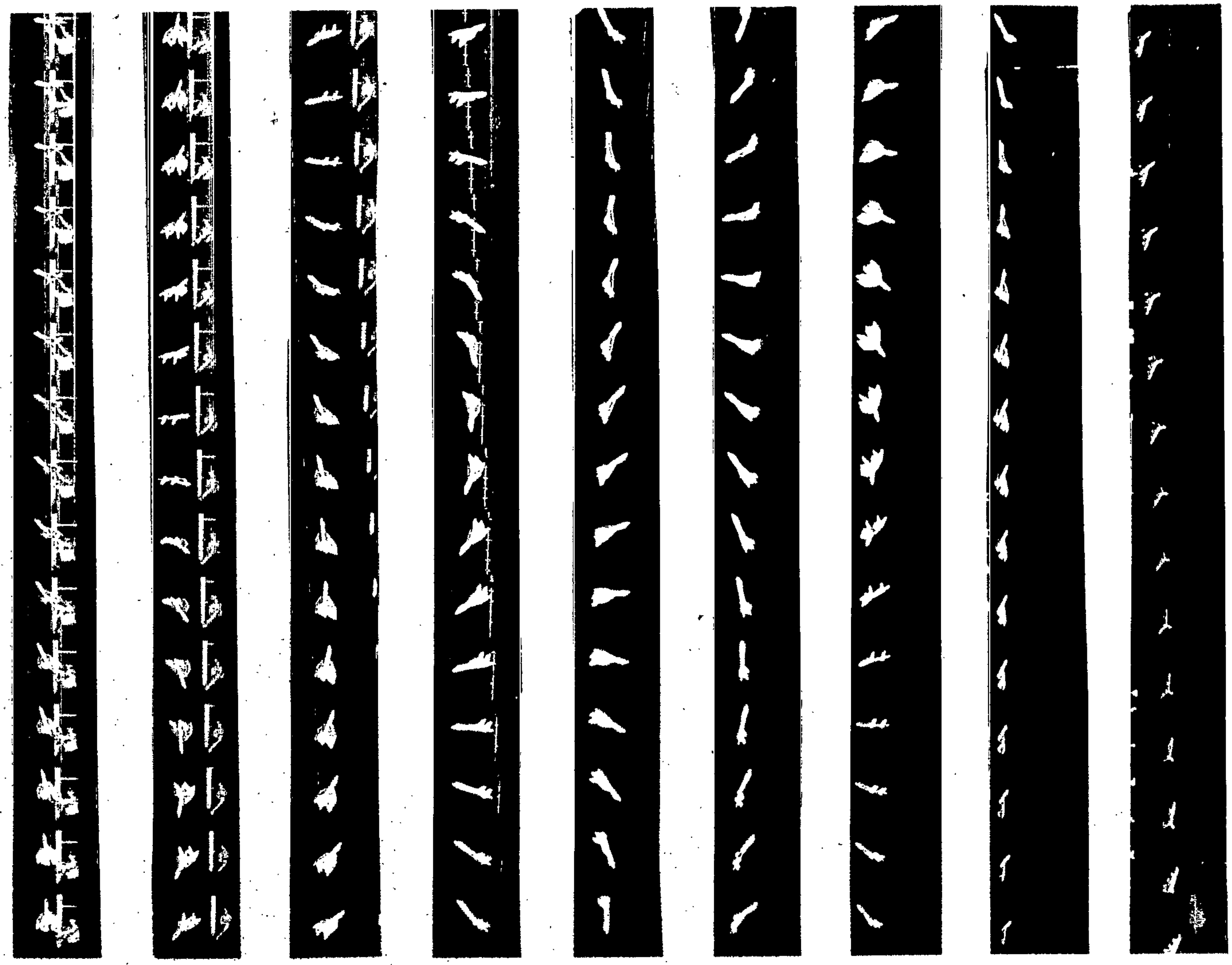

Figure 14.- Tumble of the 0.057 scale model of the XF7U-1 airplane. Center of gravity located at 24 percent of the mean aerodynamic chord; slats extended; elevators deflected full up; launched with positive pitching rotation.

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